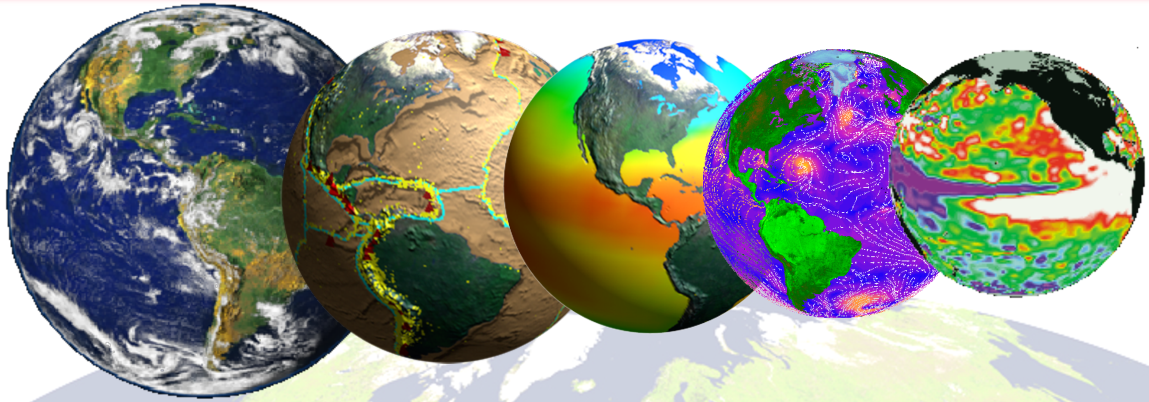


Headquarters Update to the CERES Science Team

David Considine, Program Scientist
for Earth Radiation Budget

April 28, 2020

Earth Venture Program Element

- The Earth Venture line is an important part of the overall Earth Science program, enabling advancement on many fronts and levels.
- Initiated as result of 2007 Decadal Survey Recommendation.
- Missions are competitively selected, cost capped, and PI-led:
  - EV Suborbital (EVS) - Airborne science missions;
  - EV Mission (EVM) - "Small" complete science missions (instrument(s), spacecraft, launch);
  - EV Instruments (EVI) – Hosted instrument and CubeSat investigations;
  - EV Continuity (EVC) – Missions to provide continuity measurements (New addition as recommended by 2017 DS).

Overview of ESD Earth Venture Continuity Program

- Established in response to 2017 Decadal Survey request for a low-cost program "to incentivize innovation to enable sustain observations in a more cost-effective way."

- Goal of EVC is to *demonstrate* a means to maintain the measurement continuity of important observations without undue impact on ESD flight portfolio.

- Focus on **innovative approaches** to sustain measurements at lower cost.

- PI-led, regularly solicited, cost and schedule constrained, as recommended by the DS and consistent with other EV programs.

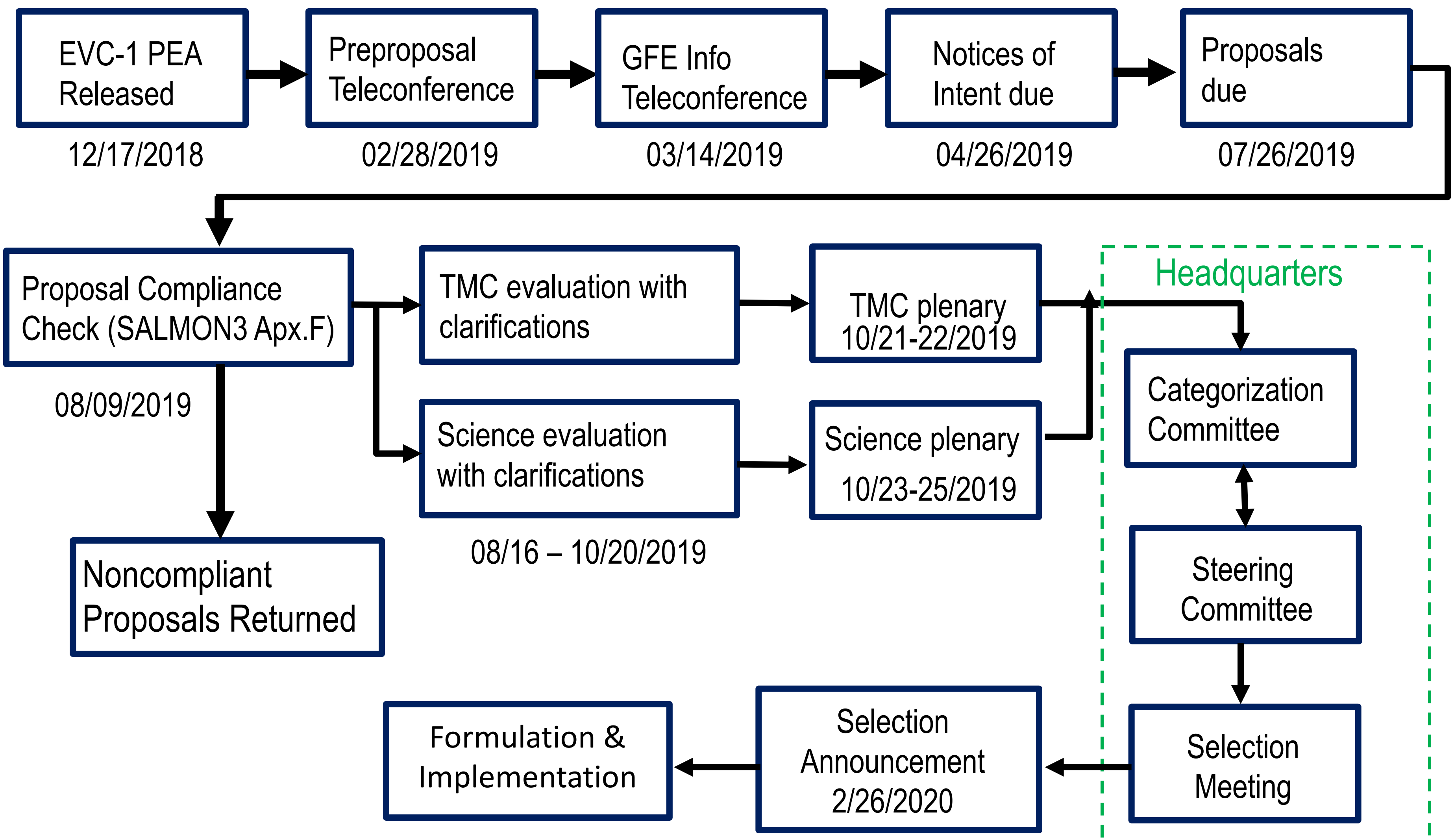
- NASA ESD will specify the measurement goal (or goals) in each solicitation.

- EVC intended to alternate every 36 months with EVI.

Earth Venture Continuity-1 Objectives

- Develop and demonstrate an innovative, cost-effective, and capable spaceborne observing system that supports continuation of the NASA ERB CDR (TOA SW, LW and Tot Radiative Fluxes).
- Measure radiances which allow the RBSP to seamlessly extend the ERB CDR, with appropriate wavelength ranges, accuracy, precision, stability, geographic and temporal sampling to advance ERB science goals and objectives.
- Demonstrate pre-flight and in-flight calibration procedures appropriate for the maintenance of long-term, multi-instrument continuity data products.
- Produce a full set of global Level 1 radiances at TOA using the proposed observing system.
- Provide to the RBSP unique algorithms and documentation, as needed, to accurately calculate radiative fluxes using the observing system.
- Deliver the observing system by a date that allows overlap with currently operational instruments sufficient to conduct the inter-calibration necessary to preserve continuity.
- Demonstrate a sustainable, innovative, and low-cost approach to acquiring the needed observations that could be used for future ERB continuity measurements.
- Enable the cost of future copies to remain low (i.e. producibility).
- Enable future technology infusion.
- Conduct research and analysis activities, using the measurements from the proposed observing system, to advance the ERB science goals.

Proposal Evaluation And Selection Flow Chart

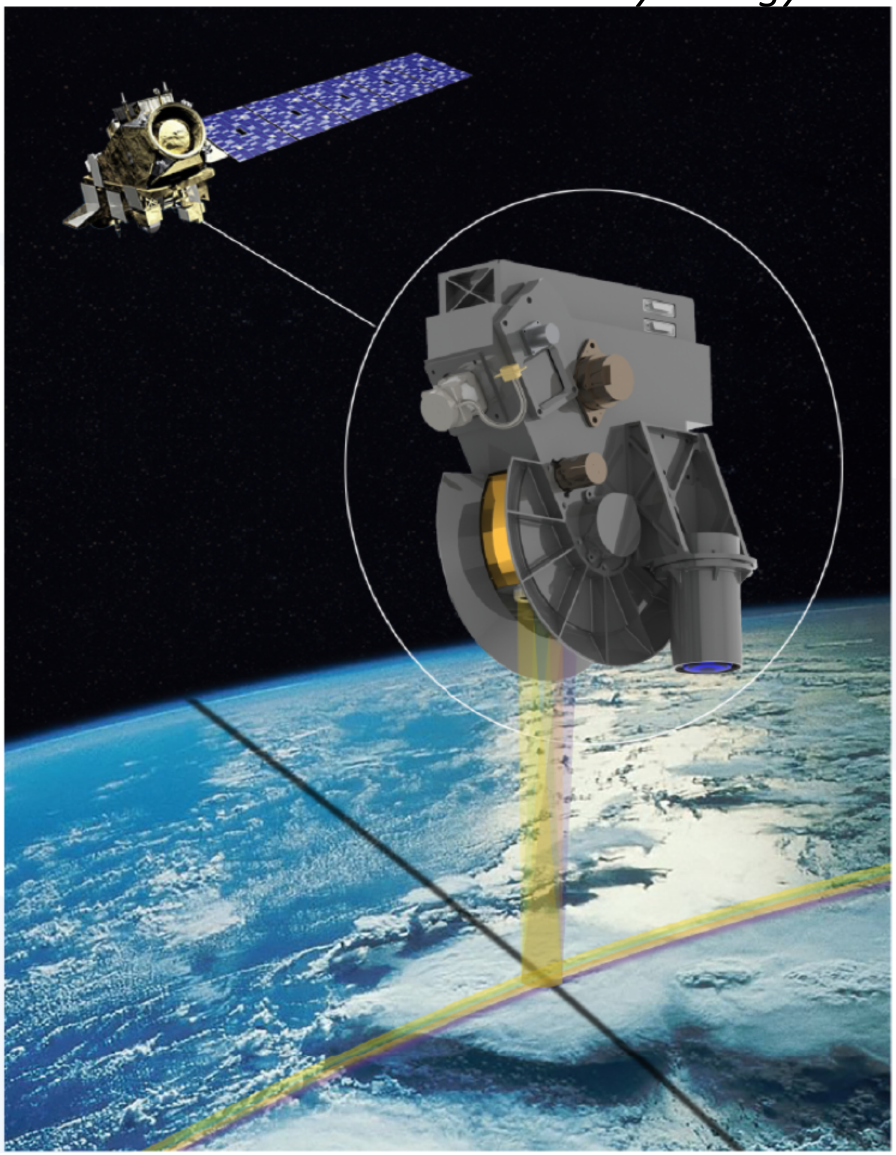


EVC-1 Selection: Libera

- 4 Proposals were evaluated.
- Two proposals received Category I ratings: Libera and CICERO
- One proposal received a Category II rating: ERBO-1
- One proposal received a Category IV rating.
- Factors influencing decision:
  - Libera judged to be most consistent with the intent of the EVC program.
  - Expected to provide Earth radiation budget continuity.
  - Judged to be most innovative proposal with most innovative and capable technology.
  - Top-notch science and science implementation.
  - Most cost-effective proposal.
  - Judged to be the best opportunity among the submitted proposals to advance Earth radiation budget science and technology.

EVC-1 Selection: Libera

(Li'be-ra), named for the daughter of Ceres in ancient Roman mythology



Provides continuity of the Clouds and the Earth's Radiant Energy System (CERES) Earth radiation budget (ERB).

- Measures integrated shortwave (0.3–5 μm), longwave (5–50 μm), total (0.3–>100 μm) and (new) split-shortwave (0.7–5 μm) radiance over 24 km nadir footprint.
- Includes a wide FOV camera for scene ID and simple ADM generation to pave way for future free-flyer ERB observing system.

Innovative technology: Electrical Substitution Radiometers using Vertically Aligned Carbon Nanotube (VACNT) detectors; VACNT-coated blackbody calibrator.

- ESR: measured signal does not depend on gain of temperature sensor or thermal properties of system, improving calibration and accuracy.

Operational modes:

- Cross-track and azimuthal scanning; on-board calibrators; solar and lunar viewing.

Flight: JPSS-3, 2027 launch; 5-year mission

- Follows pattern of CERES hosted on JPSS-1.

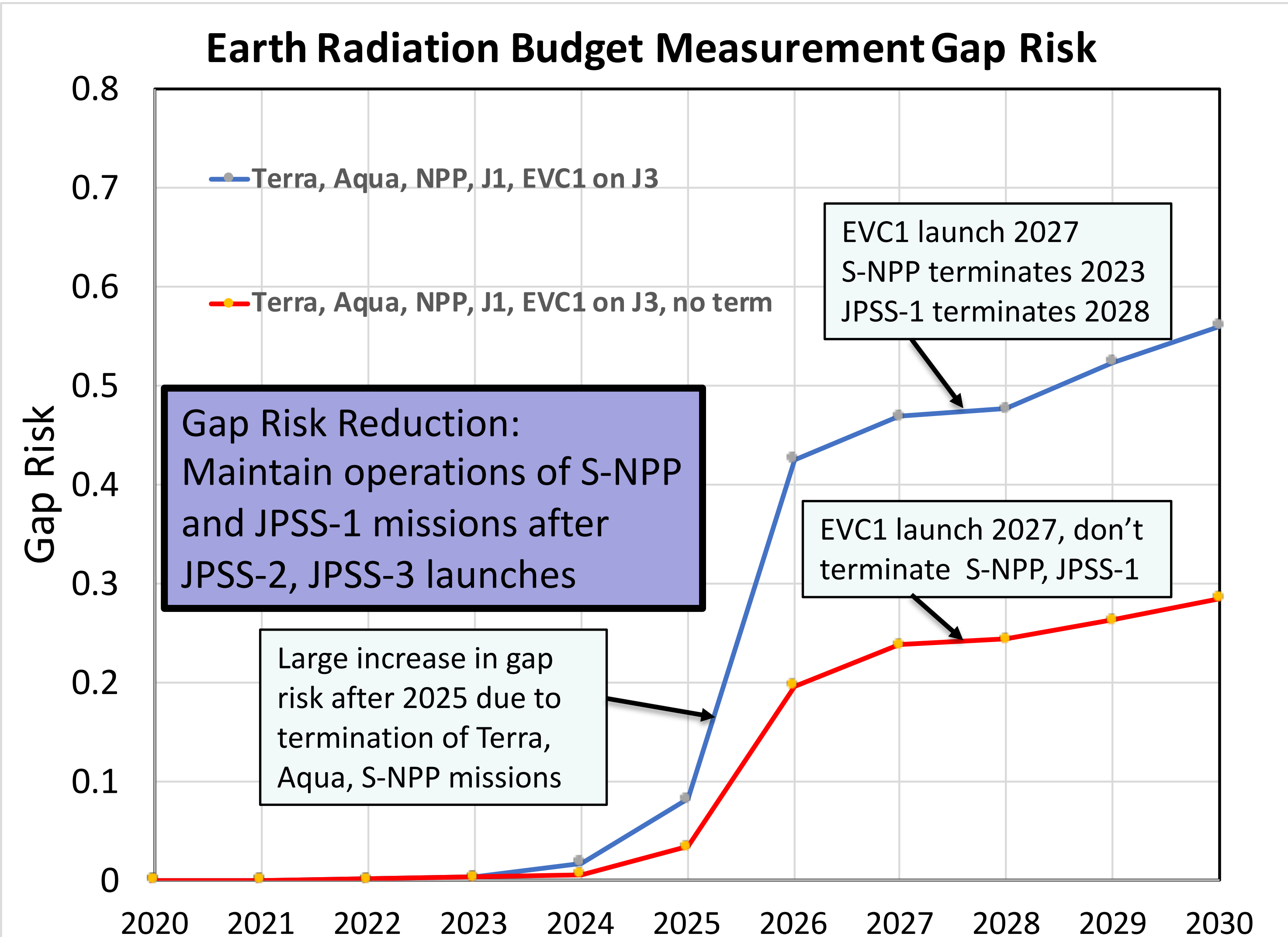
Libera Overarching Goals

1. Provide seamless continuity of the Earth Radiation Budget (ERB) Climate Data Records (CDRs)
2. Develop a self-contained, innovative and affordable observing system
3. Provide new and enhanced capabilities that support extending ERB science goals

Libera Science Objectives

1. Use the extended ERB CDR to identify & quantify processes responsible for the instantaneous to decadal variability of ERB.
   - Explore patterns of variability in ERB & cloud radiative effects (CRE).
   - Study processes responsible for ERB variability across time scales.
   - Estimate meridional energy transports, their variability, and the controls they pose on the dynamics of the ocean and atmosphere.
2. Develop Near-Infrared (NIR) and Visible (VIS) angular models and algorithms for shortwave (SW) scene identification using the Wide Field-of-View (WFOV) camera radiances.
3. Revolutionize understanding of spatiotemporal variations in SW, VIS and NIR radiative fluxes.
   - Investigate water vapor and surface albedo feedbacks and their effect on changes in absorbed SW radiation.

Estimated Gap Risk



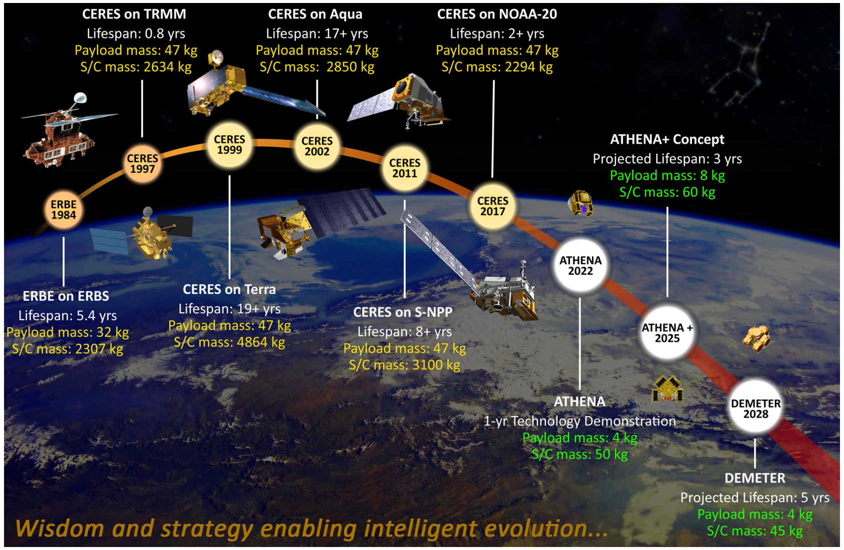
DEMETER – ROSES 2019 ESTO IIP Awardee

DEMonstrating the Emerging Technology for measuring the Earth's Radiation

PI: Dr. Anum Ashraf, LaRC

Objective

- Develop a sensorcraft that demonstrates a **game-changing** approach for measuring the Earth Radiation Budget Fundamental Climate Data Record.
- Exploit the science capability and greatly exceed data quality of current measurement by:
  - Increasing spatial resolution by factor of 10
  - Incorporating **intelligent** on-board data processing
- **Innovative** and **integrated** solution that reduces mass, power, risk, and cost, by an order of magnitude over current state-of-the-art techniques.
- Drastically reduced form-factor enables low cost flight opportunities providing more complete global diurnal sampling of radiation fields and significant risk reduction of a gap in the multi-decadal climate data record.



Approach

- Leverage 100+ years of direct experience to pro-actively influence the design and address trades involved in an integrated and intelligent manner
- Design and build a non-scanning wide-angle telescope that reduces IFOV and increases spatial resolution
- Build and test a technology demonstration unit consisting of the wide-angle telescope integrated with sensorcraft elements

Co-I's: Kory Priestley, Wenying Su, Seiji Kato, Dave Doelling, Paul Stackhouse, Mohan Shankar, J. Robert Mahan, Alexander Halterman
Collaborator: Norman Loeb
Partners: Science Systems and Applications Inc., Quartus Engineering Incorporated, NovaWurks Inc., Virginia Tech.

Key Milestones

• Project Kick-off	01/20
• Requirements Definitions Complete	03/20
• Downselection of optical architecture	05/20
• Preliminary Development Review	02/21
• Long-Lead Procurement Spec Complete	07/21
• Critical Development Review	01/22
• Assembly Integration and Test Complete	08/22
• Project Close-Out Review	12/22

TRL_{in} = 2 **TRL_{out} = 4**

Earth Science Technology Office

Black Array of Broadband Absolute Radiometers (BABAR) Earth Radiation Imager (BABAR-ERI) – ROSES 2019 ESTO IIP Awardee

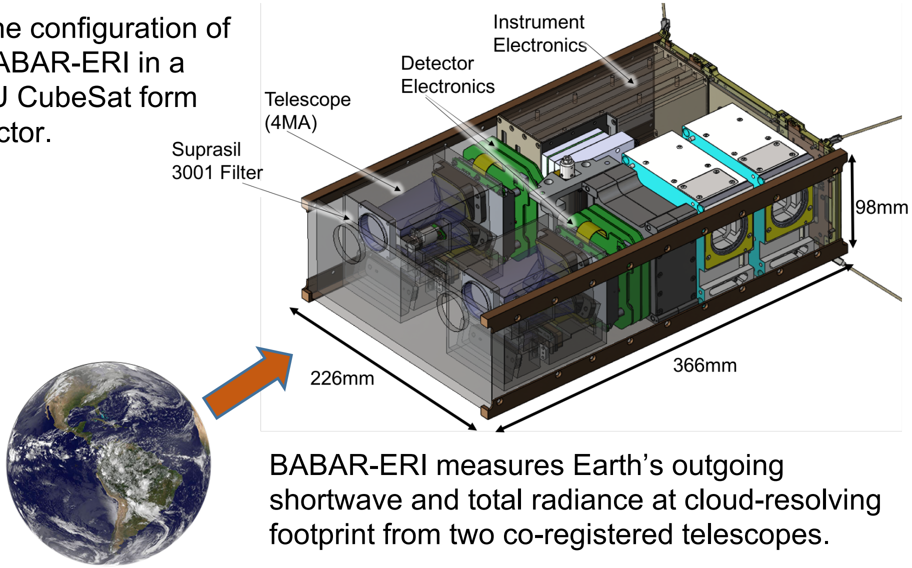
PI: Odele Coddington, LASP - Univ. of Colorado

Objective

Advance the BABAR microbolometer linear array detector technology for imaging Earth's outgoing shortwave and total radiance.

- Cloud-resolving spatial footprint resolves the spatial variability of Earth's radiation budget and constrains cloud feedback estimates.
- High-accuracy improves the best estimate of Earth's energy imbalance at the top of the atmosphere.
- Closed-loop, absolute, electrical substitution radiometers eliminate the need for an on-board calibration source.
- 6U CubeSat form factor or small Satellite form factor ensures flexible observing and implementation strategies for Earth remote sensing and reduces risks of data gaps in Earth radiation budget measurements.

The configuration of BABAR-ERI in a 6U CubeSat form factor.



BABAR-ERI measures Earth's outgoing shortwave and total radiance at cloud-resolving footprint from two co-registered telescopes.

Approach

Leverage extensive LASP/NIST technology investments from previous and ongoing programs.

•BABAR ambient-temperature, microbolometer linear array detector utilizes electrical substitution for absolute radiometry.

•Vertically aligned carbon nanotube (VACNT) absorber provides ultra-high absorptance from 0.2 µm to 100 µm.

•Two telescopes simultaneously image the shortwave and total radiance from the same ground patch.

•BABAR-ERI calibrated end-to-end over the full wavelength range against an absolute detector tailored for the instrument power levels.

Co-Is: Dave Harber, Peter Pilewskie, Sebastian Schmidt (LASP) and Michelle Stephens (NIST)

Key Milestones

Long Lead Peer Review	Oct 2020
Critical Design Review	Dec, 2020
Microbolometer subsystem complete	Oct, 2021
Chopper wheel mechanism complete	Nov, 2021
Instrument system complete	Mar, 2022
Environmental test complete	Jul, 2022

- Final Calibration Complete [TRL 6] Jan, 2023

** Potential COVID-19 impacts to this schedule.*

$TRL_{in} = 2$

Upcoming ROSES 2020 Solicitations

- Modeling, Analysis and Prediction (MAP):
  - ~$7M available, ~32 awards (~150 – 160 typically received)
  - due date 6/30/2020 (NOI due 5/22/2020)
  - Focus on Earth System Modeling and Assimilation: Clouds, Extremes, Constituents, Coupling, Assimilation, Prediction/Predictability.
- The Science of Terra, Aqua, and Suomi-NPP.
  - Solicitation has not yet been written/released, but look for an announcement later this year and a Novemberish due date.
  - Likely will be similar to the ROSES 17 solicitation:
    - Maybe $14M available for 50 – 60 awards.
    - ~250 proposals typically received.